

## COATINGS

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### MULTIFUNCTIONAL PROTECTIVE TECHNICAL COATINGS BASED ON ALUMINUM SILICATE FOR ISOTHERMAL STAMPING OF SUPER-REFRACTORY NICKEL ALLOYS

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Protective technical coatings combining the advantages of the method of oxidative heating of metals, high-temperature technical lubricants and heat-insulation coatings have been developed. It is shown that multifunctional protective technical coatings on super-refractory nickel alloys are effective.

**Key words:** nickel alloys, protective technical coating, isothermal stamping.

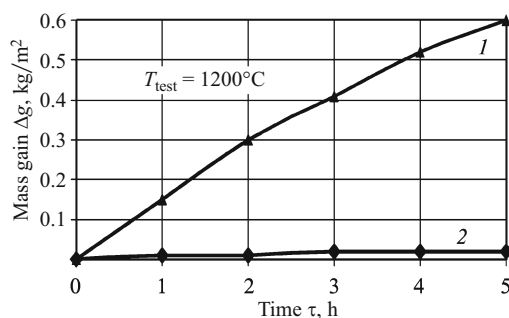
Super-refractory nickel alloys for fabricating advanced GTE disks have been developed at VIAM. Isothermal stamping in air of high-strength nickel alloys under superplasticity conditions yields disks with a homogeneous structure and high mechanical properties, which make the parts reliable and durable. However, without a multifunctional, protective, technical coating isothermal stamping is impossible under superplasticity conditions in air because the stamped pieces oxidize, which is accompanied by dry rubbing and welding of the piece to metal [1, 2].

Specialists at VIAM have developed protective technical coatings (PTCs) that combine the advantages of nonoxidative heating of metal, high-temperature technical lubricants and heat-insulation coatings. Characteristically, the quality of PTC-coated metal surfaces is just as high after high-temperature heating as after machining with a cutting tool or after heating in argon, the technical properties of PTCs are at least as good as the most effective lubricants and the coatings are serviceable at temperatures 750 – 1700°C. An advantage of PTCs is that they form during process heating under stamping, rolling or heat-treatment on blanks and final ready parts [8 – 16].

The aim of the present research was to develop multifunctional coatings for isothermal stamping in air of super-refractory nickel alloys ÉK 151, ÉP 742 and ÉI 698 in a superplasticity regime.

The main technical specifications were formulated for the coatings: protection from oxidation and burnup of alloying elements; regulated friction coefficient; preservation of the integrity of the release layer of a coating during fractional high-speed deformation of the blank; high adhesion to metal; low thermal conductivity of the release layer; simplicity of deposition before deformation and easy release of the coating from the surface of the part; and, no harmful emissions during pressure treatment.

The aluminum silicate system  $\text{Al}_2\text{O}_3\text{--CaO--SiO}_2$  was used as the basis for the PTCs and the region of glass formation in the temperature interval 1300 – 1550°C (Fig. 1) was studied. The experimental compositions were precipitation doped with refractory oxygen-free compounds capable of forming reaction-stable compounds impeding their crystalli-



**Fig. 1.** Coefficient of friction of samples of the alloy ÉK-151: 1) without coating; 2) with ÉVT 108 coating.

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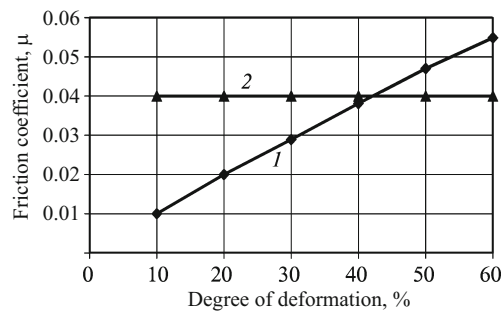


Fig. 2. Oxidizability of the refractory alloy ÉK-151: 1) without coating; 2) with ÉVT 108 coating.

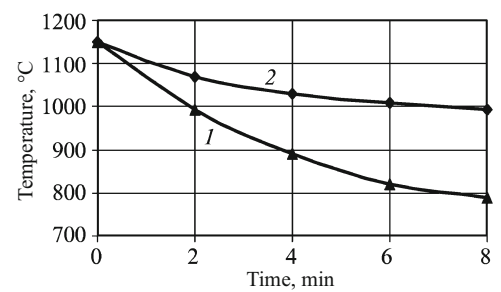


Fig. 3. Rate of cooling of blanks made of the alloy ÉK-151: 1) without coating; 2) with ÉVT 108 coating.

zation, as a result of which the synthesized compositions possessed constant viscosity and provided protection from oxidation and a regulated friction coefficient. The first multifunctional coating ÉVT 108 providing protection and functioning as a high-temperature lubricant and a release film was developed.

Main Physical-Chemical Properties of the ÉVT 108 Coating

Working temperature, °C . . . . .	950 – 1200
Protection duration, h . . . . .	10
Friction coefficient (heating at 950 – 1050 °C) . . . . .	0.02
Hear-resistance (mass gain), g/(m <sup>2</sup> · h)	
(heating at 1200 °C), ÉP 742 alloy:	
with coating . . . . .	1 – 1.5
no coating . . . . .	18 – 26
CLTE (at 100 – 800 °C), $\alpha \times 10^6, K^{-1}$ . . . . .	5.2
Density, kg/m <sup>3</sup> . . . . .	2800
Contact angle (heating at 1200 °C) . . . . .	68
Recommended coating thickness, $\mu m$ . . . . .	200 – 300

A technological scheme was developed for obtaining the slurry for the ÉVT 108 protective technical coating. It consists of the following technical operations: preparation of the initial components (drying, comminution); batching; melting the glass frit; preparation of glass frit and modifying components (crushing, grinding, drying); fabrication of the coating slurry (milling of the components); and, monitoring the quality of the slurry.

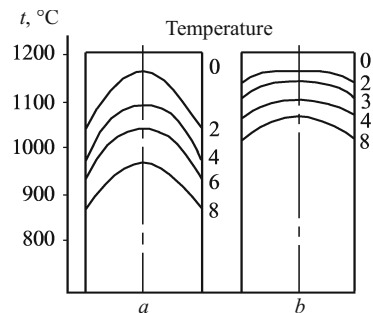


Fig. 4. Temperature distribution during cooling of a blank made of the alloy ÉK-151: a) without coating; b) with ÉVT 108 coating; numbers in the curves) cooling time, min.



Fig. 5. A turbine disk fabricated from ÉK-151 and ÉP-742 alloy with an ÉVT 108 coating by isothermal stamping in a superplasticity regime.

The multifunctional PTC ÉVT 108 on the super-refractory nickel alloys ÉK 151, ÉP 742 and ÉI 698 were shown to be effective (Figs. 1 – 4).

The experimental data obtained show that the oxidizability of nickel alloys decreases by 96 – 98%, the regulated friction coefficient with fractional degrees of deformation remains constant at 0.02 and the temperature distribution over the entire cross section of the blank is constant. The data support a homogeneous structure and high mechanical properties of disks fabricated by isothermal stamping in air under superplasticity conditions.

An exterior view of the turbine disks fabricated by isothermal stamping in air in a superplasticity regime with an ÉVT 108 coating is shown in Fig. 5.

The ÉVT 108 multifunction coating was fabricated in the experimental industrial division at FGUP VIAM.

At the request of industry more than 20 types of protective technical coatings are produced in this division: ÉVT 108, ÉVT 24, ÉVT 35, ÉVT 100, ÉVT 101, ÉVT 7, ÉVT 26 and others.

The scientific significance of the work lies in the development of the scientific principles for precipitation doping of aluminum silicate matrices by oxygen-free refractory compounds capable of forming reactively stable glassy compounds that prevent the compositions from crystallizing. The effect of the composition and dispersity of the components

on the physical-chemical and lubrication properties of coatings was studied.

The multifunctional technical coating ÉVT 108 has been adopted in the isothermal division of FGUP VIAM for stamping disks made of the alloys ÉI 698, ÉK 151 and ÉP 742 as requested by the enterprises Motor Sich, Kadvi and OMKB.

The ÉVT 108 coating enabled the following:

- nonoxidative heating of stamped parts;
- production of accurate stamped parts with untreated surfaces;
- increasing the following:
  - surface quality of intermediate products and the reliability of parts;
  - metal utilization factor to 30%;
  - surface non-machinability factor to 0.9;
  - stamping tool stability;
- decreasing the following:
  - stamping mass by 20 – 30%;
  - deformation force during stamping of intermediate products by 10 – 20%;
  - labor-intensiveness of fabrication by stamping by a factor of 4 – 5 compared with isothermal stamping in vacuum.

The development of the PTC ÉVT 108 is an innovative technical advance with no analogs in world practice.

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